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ELECTRONIC VOLUME DEVICE
[Denshi boryumu]

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[Claim(s)] /2*

[Claim 1] The electronic volume device which adjusts the output level of analog signal waveform, comprising

a means which modulates an analog amplitude waveform into a pulse signal whose pulse width is modulated according to the amplitude of analog signal waveform and inputs the signal thereof to the base of the switching circuit,

a means which acquires a voltage varying according to the volume setup value by controlling and smoothening the duty ratio of the pulse train which is repeatedly outputted from one port at a prescribed frequency and provides this voltage to an open collector of the abovementioned switching circuit, and

a means which demodulates the signal of modulated pulse width which has an amplitude corresponding to the abovementioned voltage outputted from said open collector, wherein the output level of analog-demodulated signal is adjusted by varying the duty ratio of said pulse train.

[Claim 2] An electronic volume device according to Claim 1, wherein a formula which makes the number of logic "1" to $N \cdot 10^{X/20}$ pulses (N denotes the number of logic "1" in the abovementioned pulse train) is used to generate the abovementioned variable duty ratio when the volume needs to be lowered for X decibels.

* Claim and paragraph numbers correspond to those in the foreign text.

[Detailed Explanation of the Invention]

[0001] [Industrial Application]

This invention relates to an electronic volume device which electronically adjusts the level of an analog output signal for devices, such as various audio equipment, communication equipment, etc.

[0002] [Description of the Prior Art]

This kind of conventional electronic volume device is usually constructed by combining attenuators and analog switches having different magnitudes of attenuation and operated by adjusting the partial pressure of input voltage by flipping the switches. However, this method makes the configuration of switches complicated, and moreover, for example, in order to remotely adjust the signal level from a computer, a plurality of ports are required for independently turning on and off many analog switches. As a result, a relatively complex circuit is required for computer-interface.

[0003] Moreover, as other electronic volume devices, a device using VCA (voltage control amplifier), a device using LED-CDS photocoupler, a device using FET, etc. are utilized by some applications. However, since attenuation calculation is difficult for the electronic volume devices comprising these elements, a relatively high level of analog circuit is required in order to pursue the accuracy. Furthermore, there are drawbacks for those devices that tend to cause fluctuation in their performance and are

easily affected by temperature variation, etc. Therefore, those devices cannot be made into inexpensive devices with stable performance.

[0004] [Problem(s) to be Solved by the Invention]

As mentioned above, in the case of a conventional electronic volume device, since complicated high-level techniques must be used for hardware or software for attaining accurate and stable performance in order to operate the device remotely from a computer, there are problems, such as high cost of the device and the like.

[0005] The present invention was developed to solve these problems. It is, therefore, an object of this invention to provide an electronic volume device capable of behaving accurately and stably, comprising a combination of simple hardware and software even when remotely operated from a computer connected via one port.

[0006] [Means for Solving the Problem]

The electronic volume device of this invention is configured in such a way that an analog amplitude waveform is modulated into a pulse signal of a pulse width modulating corresponding to the amplitude of analog amplitude waveform and inputted to the base of the switching circuit, while a variable voltage, which is obtained by smoothening a pulse train controlled by varying the duty ratio of the pulse train being repeatedly outputted from one port with a fixed frequency corresponding to the volume preset value, is inputted to the open collector of this switching circuit.

[0007] [Example]

The method based on this invention modulates an analog signal to a pulse signal and processes the signal thereof. That is, an analog amplitude signal is transposed to a pulse width modulated signal, and also after the output level is adjusted by adjusting the pulse amplitude (height), this pulse signal is again demodulated to an analog signal. That is, as shown in Fig. 1, the amplitude waveform of an analog signal (a) can be transposed to a pulse width modulation signal (b), and moreover, its output level is adjusted by adjusting the pulse height (voltage value) as shown in (MAX) - (MIN).

[0008] Hereafter, a concrete example of this invention is described. Fig. 2 is a block diagram illustrating an embodiment of this invention. In the figure, the reference numeral 1 denotes a pulse width modulation circuit; 2 denotes a switching circuit; 3 denotes a computer; 4 denotes a table in which bit arrays in a computer are stored; 5 denotes a smoothing circuit; and 6 denotes an LPF. An analog signal 'a' shown in Fig. 1a is inputted to the pulse width modulation circuit 1, and a pulse width modulation signal shown in Fig. 1b is outputted to a switching circuit 2 according to the amplitude. On the other hand, in the computer 3, the bit array data (shown in Fig. 3) stored in the table 4 provided as software on the RAM is repeatedly read out and outputted from a port. This output becomes a voltage value corresponding to the setup volume at the next

smoothing circuit 5 and is provided as a pull-up voltage for the open collector in the switching circuit 2.

[0009] That is, for controlling from the computer side 3 based on this invention, instead of applying a method utilizing many ports, as shown in Fig. 2, a bit string outputted in circle from one port and a value of RC variable voltage obtained by rectifying and smoothing this bit string are utilized for providing the control from the computer side. Moreover, this voltage value is adjusted by a rate of logical “1” in a bit string outputted from one port to logical “0”, that is, it is adjusted by controlling the duty ratio. Note that since the output from this port is smoothened before its use, a slow bit string output generated by a low speed interrupt is sufficient.

[0010] On the other hand, as for the pulse width modulation signal inputted into the base of the switching circuit 2 from the pulse width modulation circuit 1, since the switching circuit 2 comprises an open collector, and the voltage from the above-mentioned smoothing circuit 5 is inputted as a pull-up voltage, the amplitude (height) of an output pulse is controlled, for example, within the range of (MAX) - (MIN) shown in Fig. 1. That is, if the bit string outputted from the port entirely consists of “1” as shown in (max) in Fig. 3, the height is maximum (volume); if the entire string consists of “0” as shown in (min) in Fig. 3, the height is minimum (mute); and the section (mid) between MAX and MIN can be controlled based on the

ratio of "1" in a bit string, that is, based on the pulse height proportional to the duty ratio. In other words, it becomes possible to adjust the level of the output from the switching circuit 2 between, for example, (MAX) - (MIN) in Fig. 1.

[0011] Moreover, when the volume needs to be lowered for 6 decibels (for example) from the present volume (i.e., amplitude of an analog voice output is made into a half), the abovementioned adjustment can easily be realized by thinning out the number of logic "1" of the port output by half. Generally, in order to lower the volume for X decibels from the present volume, the program is modified so that $N \cdot 10^{X/20}$ of logical "1" in the present bit string (when the number of pulses is N) can remain in the string.

[0012] That is, the port at the computer side 3 outputs a circulated pulse train consisting of 10-bit pulses (this bit count is equivalent to the resolution of the electronic volume device). Moreover, every bit of output from this port consists of logical "1" as shown in (max) at the time of maximum volume, whereas every bit of output from this port consists of logical "0" as shown in (min) at the time of mute. In addition, in order to attenuate X decibels from the decibels at the time of maximum volume, the program is modified to reduce the ratio of "1" to $10^{X/20}$ times from 100%. In this case, for allowing RC-smoothing in the later phase to be performed as smoothly as possible, the output string should be thinned out so as

to make “1” scattered as shown in (mid) of Fig. 3 instead of making “1” concentrated at one area.

[0013] Moreover, the pulse width modulation circuit 1, which is well known, can be configured as a circuit which superimposes an analog signal to a triggering reference voltage which determines the relaxing time of multi-vibrator (for example). In addition, a low-pass filter (LFP) 6 is used to demodulate an analog signal. However, since a circuit, receiver, etc., which are fundamentally designed to handle an analog signal, are often arranged to cut off unnecessary high frequencies, a low-pass filter 6 can be eliminated when a circuit configured in this manner is used.

[0014] [Effect of the Invention]

As explained above, since the electronic volume device of this invention can remotely adjust an output level relatively accurately and stably via one port by combining simple hardware and software, costs of various communication equipment, audio equipment, electronic instruments, household products, etc. can be lowered. Furthermore, this invention provides effects such as the use of simple circuit for providing enveloping control to tone signals, etc.

[Brief Description of the Figures]

[Fig. 1] Diagram for explaining the operation theory of this invention.

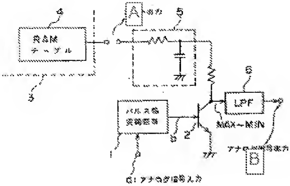
[Fig. 2] Block diagram illustrating an example of this invention.

[Fig. 3] A chart for explaining the port output used for adjusting the duty ratio with a volume setup amount.

[Explanation of the Reference Numerals]

1...Pulse width modulation circuit; 2...Switching circuit; 3...Computer; 4...RAM table; 5...Smoothing circuit; 6...LPF

Figure 2



Key:
a: Analog signal input;
A) Port output;
B) Analog signal output

Figure 3

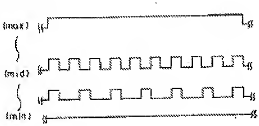


Figure 1